Some Sumatra earthquakes

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The reason for the investigation of earthquakes on and near the Indonesian isle of Sumatra follows from Vening Meinesz' gravimetric work. Vening Meinesz discovered a great belt of negative gravity values in Indonesia which runs south of Sumatra and Java, and through the Moluccas to the Philippines. This gravity belt led him to his buckling hypothesis; it is supposed that a horizontal compressive force pushes the crustal block between Sumatra and the Philippines against the ocean bottom, so that the crust undergoes plastic wrench-folding along a narrow strip. From this theory one might expect that the shallow earthquakes in Sumatra would be generated by mainly horizontal block movements, in which displacements take place along fault planes in north-west – south-east direction, in accordance with the supposed north-west compressive force.

In order to see whether this mechanism operates in the region involved, I have investigated about 20 earthquakes after the method developed by Ritsema; it is about the same method applied by Keilis Borok. In a few words this method amounts to projecting the seismic station along a seismic ray on a small sphere around the hypocentre. Compressions and dilatations of the P-waves observed in the stations must have been compressions and dilatations in the projection on the sphere. As for S-movements, one may assume that the angle between the first S-movement and the plane of incidence remains constant along the ray-path, so that the components SV and SH can be drawn on the sphere. Of course one must take into account that a movement in the station towards the epicentre is projected on the sphere as a movement away from the epicentre, which means that the SV movement must be reversed and furthermore in using S-movements one must take into account that a movement recorded by the seismograph is not the same as the true movement inside the earth. For stations with distances more than 40° from the epicentre, the ratio between true and apparent movements is a factor 2 for SV as well as for SH.

Fig. 1 shows the projection of the lower half of the sphere for a hypothetical case in which a fault plane is supposed to run north-south with a dip of 40°. The upper block moves according to the arrow, partly transcurrent and partly from below upwards, so we have here a thrust fault movement. All S-vectors in the compressive sector point to the pole of the auxiliary plane.

Fig. 2 shows an example of the fault plane solution for one of the investigated earthquakes. Open circles are dilatations, black dots are compressions. The S-movements have been composed from SH and SV. The fault plane is steeply inclined with an azimuth of N 44° E; the fault movement is partly transcurrent, the dip of the line of displacement is about 30°. The open arrows are the greatest principal stresses. They have been drawn under an angle of 25° with the fault plane, taking into account an angle of internal friction of 40°. The fault plane movement may have been caused by pressures north-south or by tensions about east-west.

The figures 3 and 4 show the results of 13 earthquakes for which a complete solution could be obtained. These earthquakes are the following:

3. 1933, June	24d	21h	54m	38s,	5°	S	104¼°	E (Visser),	m = 7,5,	shallow
5. 1935, November	25	10	03	02 ,	5½°	N	94°	E (ISS),	m = 6,5,	shallow
6. 1935, December	28	02	35	28 ,	¼°	S	98°	E (Berlage)	m = 7,9,	shallow
7. 1936, August	23	21	12	17 ,	6°	N	95°	E (ISS),	m = 7.3,	h = 40 km
8. 1938, November	15	21	00	16 ,	5°	S	99°	E (Berlage)	m = 6.5,	shallow
11. 1946, March	26	17	09	03 ,	3°	S	102°	E (Gutenberg),	m = 6.7,	shallow
12. 1946, May	08	05	20	20 ,	½°	S	99½°	E (ISS),	m = 7.1,	shallow
13. 1949, May	09	13	36	18 ,	5°	N	95°	E (USCGS),	m = 6.7,	shallow
14. 1949, June	24	22	38	36 ,	7°	S	105°	E (USCGS),	m = 7.0,	shallow
16. 1937, July	01	11	49	40 ,	3°	N	96°	E (ISS),	m = 6.7,	h = 110 km
17. 1937, August	04	23	35	18 ,	6°	N	94½°	E (De Boer),	m = 6.0,	h = 120 km
20. 1938, August	25	01	28	14 ,	5°	S	102°	E (Berlage),	m = 6.9,	h = 100 km
22. 1944, January	05	21	12	43 ,	3½°	S	102°	E (Gutenberg),	m = 7.0,	h = 60 km

For the lacking numbers no clear solution could be obtained.

Fig. 3 shows the strikes of the fault planes. They are either perpendicular to the gravity belt or parallel to it; the dips of the fault planes

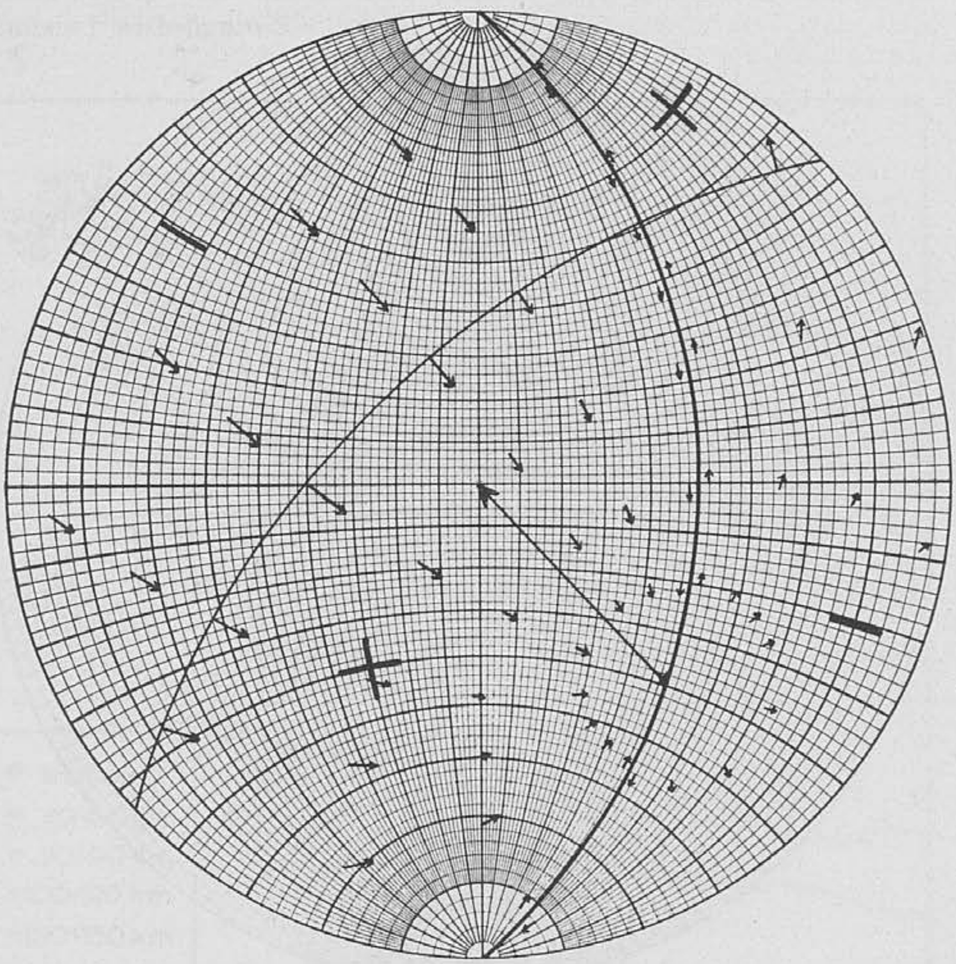

Fig. 1. – Repartition of compressions (+) and dilatations (—) of first P-movements and directions of first S-movements around the hypocentre of a hypothetical earthquake; the fault-plane is supposed north-south with a dip of 40° to east. The upper block moves upward and partly transcurrent according to the arrow. The movements on the lower half of a sphere around the hypocentre have been drawn. The thick circle represents the faultplane, the thin circle the auxiliary plane.

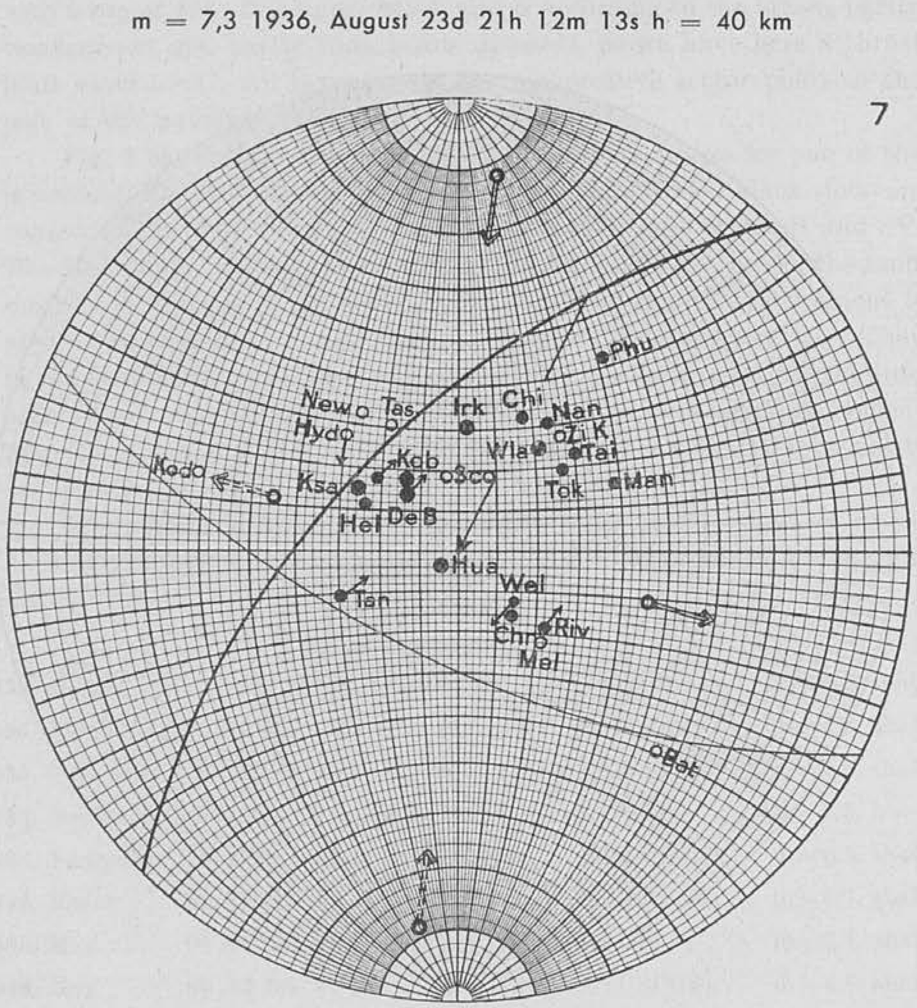

Fig. 2. – Fault-plane solution for one of the investigated earthquakes (number 7, off the north coast of Sumatra, see also figures 3 and 4). The fault-plane has the azimuth N 44° E, the dip is 60°. The fault movement is partly transcurrent with a dip of 30°. The open arrows are the greatest pressures and tensions which may have caused the earthquake. Pressures and tensions acting through the upper half sphere have been indicated by broken arrows.

are mostly large. The dips of the displacement-vectors are smaller than 45° in general, so the movements are largely horizontal. The displacements are in general perpendicular to the zone. The meaning of the figures and symbols will be clear when comparing those for earthquake number 7 with figure 2.

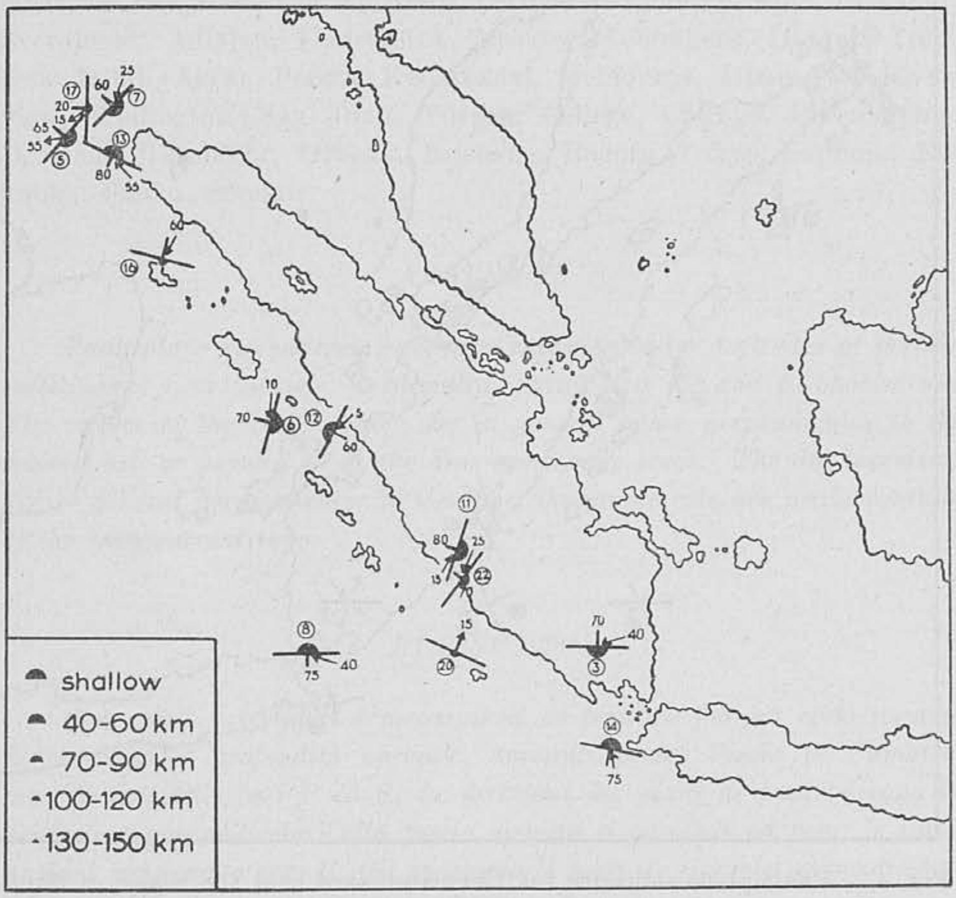

Fig. 3. – Fault-plane solutions for 13 earthquakes near the island of Sumatra. For each epicentre the strike of the fault-plane has been drawn and the direction of the displacement of the upper block; the figure in a circle is the number of the earthquake, the other figures are the dips of the fault-plane and of the displacement-vector.

Fig. 4 shows again the fault planes, but now the greatest principal stresses have been drawn and the tensions perpendicular to them. These figures show that many transcurrent faults, dextral as well as sinistral in the sense used by Hodgson. The deeper earthquakes show more purely normal fault movements or thrust fault movements (*).

The conclusion is that there is some correlation between the belt of gravity and seismicity and the fault movements. There is some preference for horizontal pressures perpendicular to the zone but we do not find the simple transcurrent fault movements which might be expected after the mechanism supposed in the theory of Vening Meinesz.

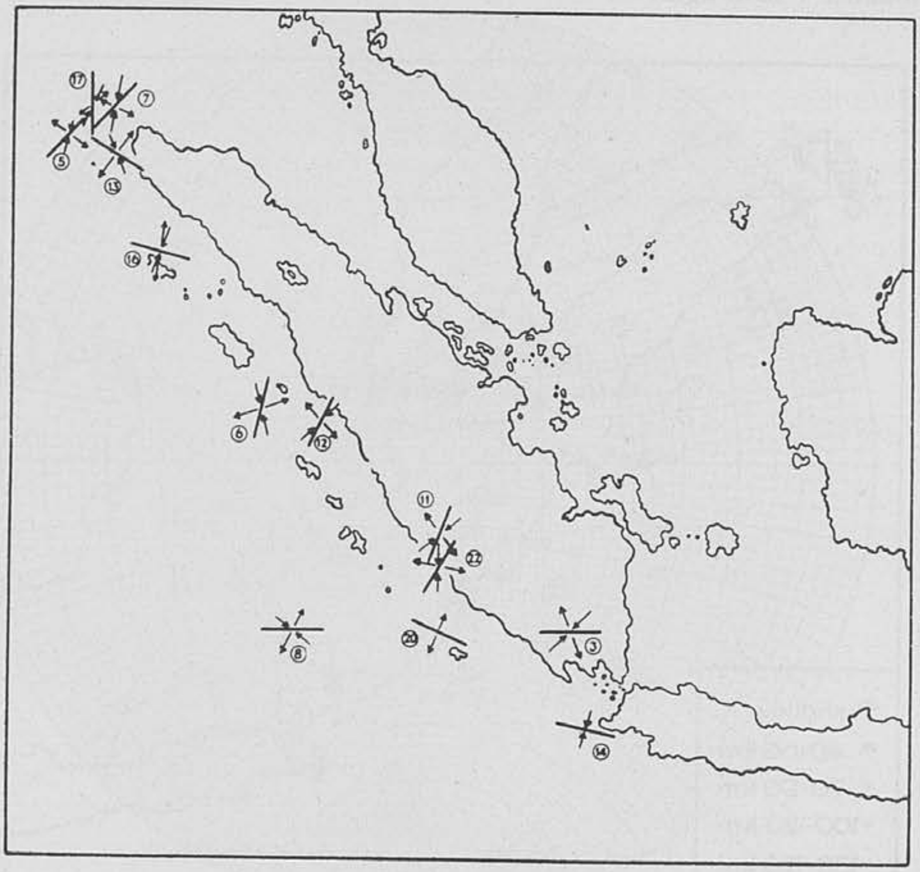

Fig. 4. – Fault-plane solutions for 13 earthquakes near the island of Sumatra. For each epicentre the strike of the fault-plane has been drawn. The arrows are the horizontal projections of the greatest principal pressures and tensions, which may have caused the earthquakes. The number of the earthquake is indicated.

(*) A full account of the investigation will appear as a publication of the Royal Netherlands Meteorological Institute.

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ABSTRACT

Fault plane mechanisms have been investigated for a number of shallow earthquakes near the isle of Sumatra, using first P- and S- movements. The strikes of the fault planes are in general either perpendicular to the seismic belt or parallel to it; the dips are mostly large. The displacements are in general perpendicular to the zone, the movements are predominantly of the transcurrent type.

RIASSUNTO

Sono stati investigati i meccanismi di frattura per un certo numero di terremoti a profondità normale, avvenuti presso l'isola di Sumatra, facendo uso delle fasi P ed S. Le direzioni dei piani di frattura sono in generale o perpendicolari alla fascia sismica o paralleli ad essa; le inclinazioni sono molto grandi. Gli spostamenti sono in generale perpendicolari alla zona, i movimenti sono prevalentemente associati a scorrimento.

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